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Carbon Dioxide Treatment of Golden Delicious Apples

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ABSTRACT

In central Washington, Golden Delicious apples have responded to carbon dioxide (CO₂) treatment with significant retention of firmness, which permits extension of the packing and marketing season. Apples treated with CO₂ and held in controlled atmosphere (CA) storage for 5 to 9 months were 2 to 3 pounds firmer than fruit in refrigerated storage. Treated apples were graded and packed in February, March, and April without excessive bruising and in a very acceptable condition. Reports from retail markets indicate CO₂-treated fruit have a longer shelf life than apples stored in regular or CA storage.

KEYWORDS: Controlled atmospheres, carbon dioxide treatment, harvest maturities, shelf life, commercial storage, fruit firmness, postharvest treatments, carbon dioxide injury, temperature control

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UNITED STATES DEPARTMENT OF AGRICULTURE
In Cooperation With
Washington State University Area Extension Office

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CARBON DIOXIDE TREATMENT OF GOLDEN DELICIOUS APPLES

By Kenneth L. Olsen and Richard D. Bartram¹

INTRODUCTION

In central Washington, Golden Delicious apples have responded to carbon dioxide (CO₂) treatment with significant retention of firmness, which permits extension of the packing and marketing season. Apples treated with CO₂ and held in controlled atmosphere (CA) storage for 5 to 9 months were 2 to 3 pounds firmer than fruit in refrigerated storage. Treated apples were graded and packed in February, March, and April without excessive bruising and in a very acceptable condition. Reports from retail markets indicate CO₂-treated fruit have a longer shelf life than apples stored in regular or CA storage.

The following recommendations are based on research and commercial experience over a 3-year period (1974-76) throughout the State of Washington in 139 different rooms. Successful use of postharvest CO₂-enriched storage atmospheres is dependent upon a managed program that includes several operations: Fruit selection, postharvest treatment for decay and scald, filling the CA room, CO₂ treatment, posttreatment storage, packing, and handling.

FRUIT SELECTION

Golden Delicious apples with correct maturity are required for good response to this treatment. The fruit should come from orchards with a moderate state of vigor and uniform tree age and growth. Trees that are weak, low in vigor, in frost pockets, or with light crops should be avoided. The Golden Delicious that responded well in commercial storage were harvested when there was a good fruit finish with rounded calyx, pressures in the range of 17 to 19 pounds, 11 percent or better soluble solids, and color change. The color change is from a light green to greenish white or greenish yellow, depending on the season. The days from full bloom will vary with the season and the orchard. In the 1975 crop, fruit that provided the best response with the least injury were harvested in the 133- to 143-day period from full bloom. In 1976, fruit harvested during the 137- to 145-day period from full bloom gave good response. Apples harvested in an early state of maturity retained the highest levels of firmness.

¹
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POSTHARVEST TREATMENT FOR DECAY AND SCALD

Since many of the CO₂-treated Golden Delicious are intended for long storage, we² suggest they be treated for decay control in the immediate postharvest period. Any apples that are dipped or flooded for decay control or other purposes should be permitted to drain thoroughly, usually 2 to 3 hours before placement in cold storage and CO₂ treatment. Make certain the fruit surfaces are dry. Particularly note the calyx area where droplets of moisture may be retained. Recent research has shown that surface³moisture in combination with the CO₂ atmosphere will result in surface injury.

Control of storage scald has been achieved in⁴ the packing operation provided packing is done within 17 weeks of harvest.

FILLING THE ROOM

To be most beneficial, the CO₂ treatment must begin as soon as possible after the fruit are harvested. If treatment is delayed 20 days, there is no benefit. Five days or less filling period has given excellent response. The maximum period for filling a room is 5 days.

Refrigeration capacity should be adequate for rapid cooling as the room is loaded. Closing of the room and initiation of the CO₂ treatment should be started as soon as the room is filled. Cooling should continue throughout the treatment period.

Proper spacing of the stacks of bins to provide for optimum air circulation is essential for rapid cooling and later maintenance of the fruit temperature. Since CO₂ gas is heavier than air, good air circulation (through proper stacking and continuous operation of fans) is essential for the thorough mixing of the gases in the storage atmosphere.

CO₂ TREATMENT

A catalytic oxygen (O₂) burner, if available, may be used to remove O₂ and return CO₂ to the room. The O₂ level can be reduced to less than 10 percent by burning. The addition of CO₂ will further dilute the O₂ and respiration of the apples continues to remove O₂ from the room. Within 24 hours after burning has started, CO₂ should be added to the room to bring the concentration

²

Washington State Cooperative Extension Service. Decay control on apples and pears: A summary of research and practical experience with mertect and benlate. Area Ext. Off., Wenatchee, Wash. 1976.

³

Lau, Oi-lim, and Looney, Norman E. Water dips increase CO₂ associated peel injury in 'Golden Delicious' apple. HortScience 12(5):503-504. 1977.

⁴

Pierson, C.F. Control of storage scald of apples. Cooperative Extension Service, Wenatchee, Wash. 98801.

to the desired level. The CO₂ should be introduced immediately behind or in front of the evaporator fan to insure good mixing. The fan should be running whenever CO₂ is flowing into the room, that is, gas should not be introduced during the defrost if the fans are stopped. If the air is recirculated through the burner from the cold room, CO₂ may be added during the burning period. The O₂ level does not appear to be critical during this period, but it should be somewhere between 1 and 5 percent during the treatment period.

A CO₂ level of 15 to 17 percent maintained for 8 to 9 days has consistently produced the best response in retention of fruit firmness (fig. 1). This is usually preceded by 24 to 36 hours of continuous burning time. Total treatment time, including burning time, should not exceed 10 days.⁵



Figure 1.--Pressure testing Golden Delicious apples to establish degree of firmness.

⁵ Couey, M., and Olsen, K. The commercial use of prestorage CO₂ treatment to retain firmness and quality in 'Golden Delicious'. In Proceedings of the National Controlled Atmosphere Research Conference, Michigan State University, April 5-7, 1977, East Lansing, Mich.

Many rooms have been treated with 13- to 14-percent CO₂ levels for 10 days plus 1 or 2 days burning time. At the end of 6 months, this level provided about 1/2 to 2/3 as much retention of firmness after 6 months in storage. *Burning time should not exceed 36 hours, and the total treatment time, burning plus treatment, should not exceed 12 days.* Treatment levels below 13-percent CO₂ have resulted in less response and, at times, no measurable response. Treatment levels of 20-percent CO₂ or higher have given excessive internal injury, which cannot be visually detected at the time of packing. (See section on CO₂ Injury.)

When CO₂ is added to the room, the atmospheric pressure is increased. Provisions should be made for venting the excessive pressure to prevent breaking the seal of the CA room.

CO₂ may be introduced as solid dry ice, as liquid from siphon-type cylinders, or as a gas from conventional cylinders.⁶ The same weight of CO₂ is required regardless of its source. Adding CO₂ to the room sweeps some of the atmosphere in the room away, so this amount of gas should be considered in calculating the amount of CO₂ to add. The following formula will give the approximate amount of CO₂ that should be added under different conditions:

$$A = \frac{0.144 V (P_f - P)}{100 - P_f}$$

A = CO₂ required in pounds

V = Room volume in cubic feet

P_f = Percent CO₂ required

P = Percent CO₂ already in room

CO₂ INJURY

CO₂ treatment has caused external and internal injury to Golden Delicious apples. External injury usually appears as irregular tan to light-brown areas on the skin surface (fig. 2). These areas become slightly depressed following loss of moisture during storage. Injured areas may range from a very small spot up to one-half of the surface of the apple. Injury occurs during the treatment period with no further increase of the injured area in the period following treatment. Internal injury appears as voids (holes) in the flesh with a slightly brownish lining of the holes.

Damage by CO₂ treatment has occurred to only a small portion of the fruit treated in Washington; however, in a few individual grower lots, damage has been severe. External injury of commercially treated Golden Delicious in the 3-year period occurred on 1.5 percent of all fruit, ranging from no injury on most grower lots to as much as 30 percent injury on a few lots. Factors that

⁶ Compressed Gas Association. Handbook of Compressed Gases. Pp. 58-59. Reinolds Publishing Corp. 1966.

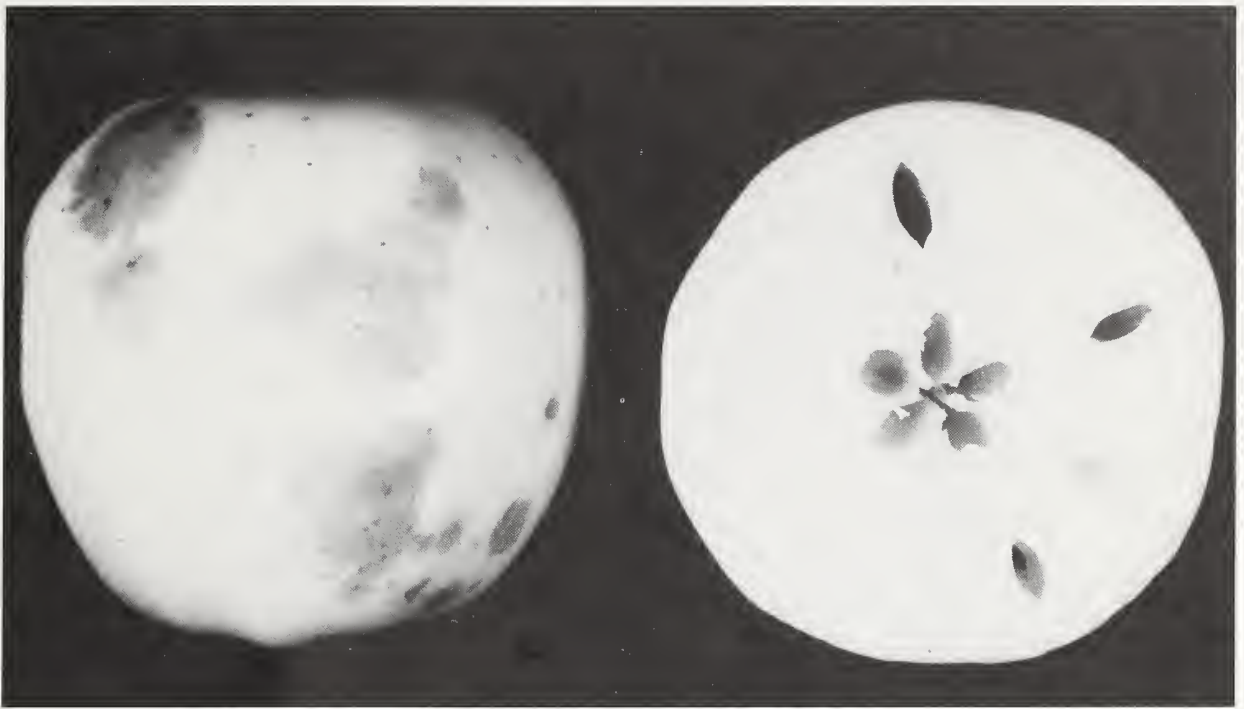


Figure 2.--Severe external (left) and internal (right) injury caused by CO₂ over-treatment or poor maturity.

seem to contribute to external injury include immature (green) fruit, too long a treatment period, fruit from frost-prone locations or frost-damaged crops, wet fruit, and inadequate air circulation. Internal injury has resulted from treatment of mature fruit with 20 percent or higher CO₂ and treatment periods of more than 10 days.

POSTTREATMENT STORAGE

At the end of the treatment, the room should be opened and aired out or flushed completely. This removes the CO₂ and restores the normal atmospheric conditions. If the CO₂ is removed by scrubbing, then the treatment period should be shortened so that the fruit is not exposed to CO₂ levels of more than 10 percent for longer than 10 days. As soon as the room is flushed, the maximum retention of firmness can be obtained by returning the room to CA conditions of 2- to 3-percent O₂ and less than 2-percent CO₂ with good temperature control. Immediately following CO₂ treatment, no measurable difference in the firmness of apples is likely to be identified. Only after several months of additional storage will the firmness differences be exhibited. By returning the apples immediately to CA conditions, the greatest retention of firmness will be obtained for the longer storage period of 5 to 9 months. If the apples are placed in refrigerated storage with excellent temperature control, they will experience only about one-half the firmness retention they would have experienced in CA storage (fig. 3).

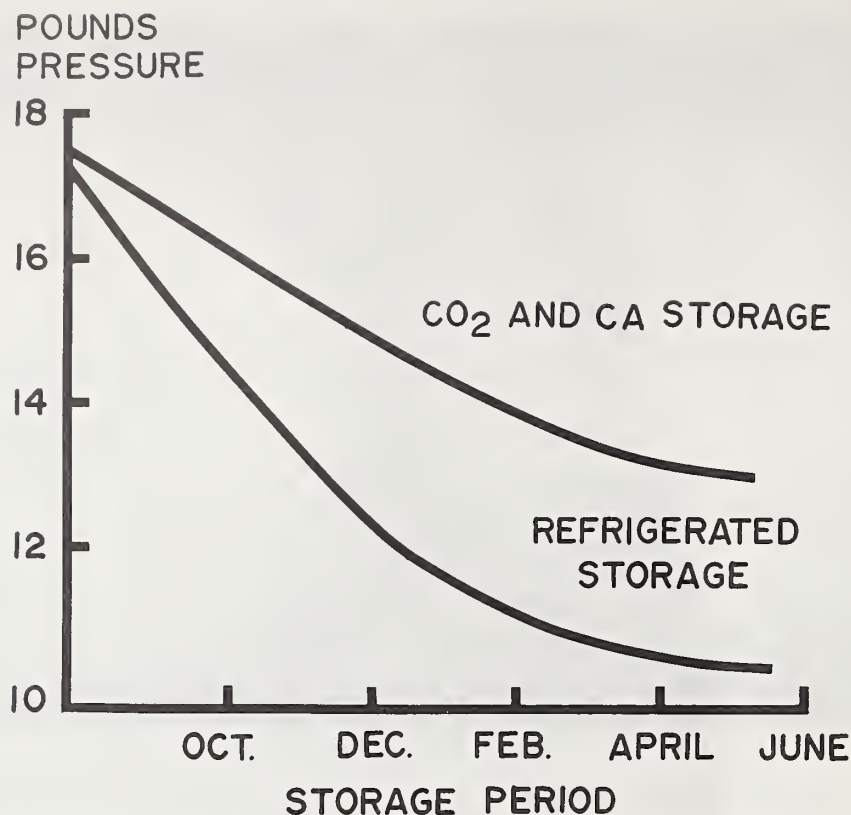


Figure 3.--Average pressures of Golden Delicious apples (size 100) in CO₂, CA, and refrigerated storage harvested between 142 to 147 days from full bloom.

PACKING AND HANDLING

The length of time the apples are left in storage before packing depends upon the packing operations and marketing program requirements. Packing in February, March, or April was satisfactory. Apples packed before February minimized bruising, but the possibility of increased decay and other physiological disorders developed when the apples were to be stored an additional 3 to 5 months. Apples packed later than April increased the possibility of bruising.

Some fruit ready for packing in February, March, or April may be sensitive to bruising unless they are conditioned for the packing operation. Apples placed in excellent storage with high humidity are turgid and should be observed for bruising potential before packing. Immediate packing of apples from CA storage generally results in small machine bruises. Permitting the fruit to be in a storage situation that results in a loss of a small amount of moisture (less than 1 percent) will condition this fruit. This conditioning will give the fruit a resilience that overcomes bruising during the packing. This condition must be observed even with Golden Delicious that may average 15 pounds firmness in March.

Although this is a complex process, requiring selective harvest, 3- to 5-day room filling, treatment with specific CO₂, and temperature control with continued CA storage, outstanding benefits have been obtained.

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